Emergent complexity in marine ecosystem models: When does emergence arise as models increase in complexity?

NERC GW4+ Doctoral Training Partnership

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Scientific background

Climate change remains an existential threat to established marine communities and human exploitation of the oceans for food and other services. Marine biota are vulnerable to rising temperatures, ocean acidification and other anthropogenic pressures such as pollution. Numerical simulations are the only tools available to predict how these factors will influence marine life under climate change. Are the current models fit for purpose?

Emergent properties are coherent structures, patterns, relationships and material fluxes that are observed in nature and can be reproduced by a sufficiently complex model. However, complex models require more computational resources. Most of the models submitted to the fifth coupled model intercomparison project (CMIP5) had relatively simple marine biogeochemical models, which would not be capable of producing many of the emergent properties seen in a fully featured model.

It is not clear whether the absence of these emergent properties in the marine ecosystem impacts future projections. This project would address whether the absence of emergent properties in simpler models impacts the models ability to represent natural marine ecosystem behaviour.

Research methodology and Training

This project centres on how model complexity leads to emergence of natural behaviour, investigating the following emergent properties:

- The deep ocean is the world's largest carbon reservoir, and marine bacteria may be a significant contributor to the drawdown of atmospheric carbon. What impact does bacterial behaviour have on the deep ocean carbon reservoir?
- Phytoplankton are the base of the marine food chain, incredibly diverse and produce half the oxygen in the atmosphere. Are simpler ecosystem models able to produce a sufficiently accurate representation of phytoplankton mediated fluxes?
- Zooplankton are simultaneously grazers, predators and prey. What impact do changes to the model of their community have on the zooplankton community, the phytoplankton community and the carbon cycle?

These questions would be initially investigated using a one dimensional GOTM-ERSEM water column model, allowing rapid prototyping. Initially, the model would simulate conditions at the L4 site in the Western English Channel, then testing would expand to several other 1D sites. Once multiple 1D candidate simulations have been prepared, the student would start one of the following three dimensional simulations: either the global 1 degree NEMO-ERSEM or the Atlantic Margin Model, which covers the North East Atlantic and North Sea.

Person Specification

This project is suitable for candidates with a master's degree in a mathematically or computationally intensive scientific field, (such as physics, chemistry, mathematics or engineering) with a demonstrable interest in marine science and climate, or who have a background in oceanography or similar with a proven track record of modelling. The candidate will learn how to write and understand programming, run simulations, evaluate models, test hypotheses, publish results and present at conferences.